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-	28	((5559794") or ("5577118") or ("5539391") or ("5565929") or ("5379341") or ("5513242") or ("5410738") or ("5555258") or ("5517553") or ("5566205") or ("d374675") or ("5465401") or ("4675653") or ("5195130") or ("5577118")).PN.	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM TDB	2002/11/18 10:49
-	10	"9203884"	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM TDB	2002/11/18 10:50
-	1980	browser with (phone or telephone)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM TDB	2002/11/18 10:58

-	88	705/26,27.ccls. and (browser with (phone or telephone))	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM TDB	2002/11/18 10:58
-	436089	mobile or cellular	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM TDB	2002/11/18 10:59
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How Cell Phones Work

by Marshall Brain and Jeff Tyson

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The Cell Approach

One of the most interesting things about a cell phone is that it is actually a radio -- an extremely sophisticated radio, but a radio nonetheless. The telephone was invented by Alexander Graham Bell in 1876, and wireless communication can trace its roots to the invention of the radio by Nikolai Tesla in the 1880s (formally presented in 1894 by a young Italian named Guglielmo Marconi). It was only natural that these two great technologies would eventually be combined!

In the dark ages before cell phones, people who really needed mobile-communications ability installed **radio telephones** in their cars. In the radio-telephone system, there was one central antenna tower per city, and perhaps **25 channels** available on that tower. This **central antenna** meant that the phone in your car needed a powerful transmitter -- big enough to transmit 40 or 50 miles (about 70 km). It also meant that

Cool Facts

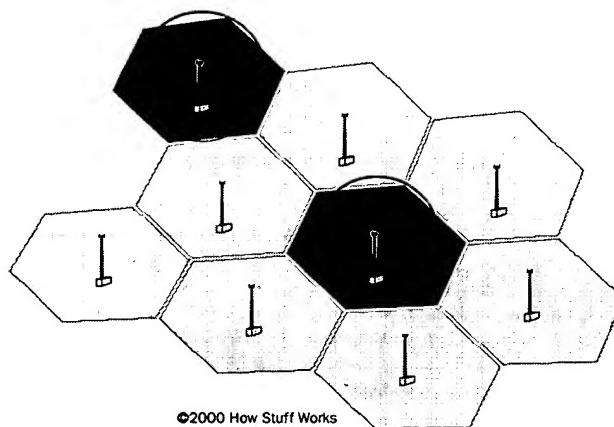
- Most newer digital cellular phones have some sort of entertainment programs on them, ranging from simple dice-throwing games to memory and logic puzzles.
- Approximately 20 percent of American teens (more girls than boys) own a cellular phone.
- Cellular phones are more popular in European countries than they are in the United States -- more than 60 percent of Europeans own a cell phone, compared to about 40 percent of Americans.

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- [What is the difference between analog and digital cell phones?](#)
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not many people could use radio telephones -- there just were not enough channels.

The genius of the cellular system is the division of a city into **small cells**. This allows extensive **frequency reuse** across a city, so that millions of people can use cell phones simultaneously. In a typical analog cell-phone system in the United States, the cell-phone carrier receives about **800 frequencies** to use across the city. The carrier chops up the city into cells. Each cell is typically sized at about **10 square miles** (26 square kilometers). Cells are normally thought of as hexagons on a big **hexagonal grid**, like this:



Because cell phones and base stations use low-power transmitters, the same frequencies can be reused in non-adjacent cells. The two purple cells can reuse the same frequencies.

Each cell has a **base station** that consists of a tower and a small building containing the radio equipment (more on base stations later).

A single cell in an analog system uses one-seventh of the available duplex voice channels. That is, each cell (of the seven on a hexagonal grid) is using one-seventh of the available channels so it has a unique set of

frequencies and there are no collisions:

Coverage Maps

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- A cell-phone carrier typically gets **832 radio frequencies** to use in a city.
- Each cell phone uses two frequencies per call -- a duplex channel -- so there are typically **395**

- voice channels** per carrier. (The other 42 frequencies are used for **control channels** -- more on this on the [next page](#).)
- Therefore, each cell has about **56 voice channels** available.

In other words, in any cell, 56 people can be talking on their cell phone at one time. With digital transmission methods, the number of available channels increases. For example, a **TDMA-based** digital system can carry three times as many calls as an analog system, so each cell has about 168 channels available (see [this page](#) for lots more information on TDMA, CDMA, GSM and other digital cell-phone techniques).

Cell phones have **low-power transmitters** in them. Many cell phones have two signal strengths: 0.6 watts and 3 watts (for comparison, most CB radios transmit at 4 watts). The base station is also transmitting at low power. Low-power transmitters have two advantages:

- The **transmissions** of a base station and the phones within its cell do not make it very far outside that cell. Therefore, in the figure above, both of the purple cells can **reuse the same 56 frequencies**. The same frequencies can be reused extensively across the city.
- The **power consumption** of the cell phone, which is normally battery-operated, is relatively low. Low power means small batteries, and this is what has made handheld cellular phones possible.

The cellular approach requires a large number of base stations in a city of any size. A typical large city can have hundreds of towers. But because so many people are using cell phones, costs remain low per user. Each carrier in each city also runs one central office called the **Mobile Telephone Switching Office** (MTSO). This office handles all of the phone connections to the normal land-based phone system, and controls all of the base stations in the region.

In the next section, you'll find out what happens as you (and your cell phone) move from cell to cell.

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